# DESCRIPTION, AND USE,

OF THE

*Telescopical Mother-of-Pearl*

# MICROMETER.

INVENTED BY

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# CONTENTS.

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# TELESCOPICAL MOTHER-OF-PEARL

# MICROMETER.



A MICROMETER, as the etymology of the word imports, is an inſtrument uſeful for ſmall admeaſurement; and as ſmall objects are generally obſerved through magnifying inſtruments, the Micrometers are therefore adapted to microſcopes or teleſcopes; in the former, being uſed for meaſuring lineal extenſions, as the diameter of a hair, the length of an inſect, &c.; and in the latter, for meaſuring ſmall angles: thus, if two lines are ſuppoſed to be drawn from the oppoſite edges of the ſun's diſk to

the eye of the obſerver, the angle formed by thoſe two lines, which is the angle ſubtended by the ſun, may be meaſured by means of a teleſcope furniſhed with a Micrometer.

Many different Micrometers have been invented, and are now in uſe; all of which, however, may be divided into two claſſes: in one of which the parts are fixed, and in the other have motion. The Micrometers of the former ſort, conſiſt moſtly of fine wires, or hairs, variouſly diſpoſed and ſituated within the teleſcope, juſt where the image of the object is formed. In order to determine an angle with thoſe Micrometers, a good deal of calculation is generally requiſite.——The Micrometers of the other ſort, of which there is a great variety, ſome being made with moveable parallel wires, others with priſms, others again with a combination of lenſes, and ſo on, are more or leſs ſubject to ſeveral inconveniences; the principal of which are the following: 1ſt, Their motions generally

rally depend upon the action of a ſcrew, and of courſe the imperfections of its threads; and the greater or leſs quantity of motion loſt, which is obſervable in moving a ſcrew, eſpecially when ſmall, occaſion a conſiderable error in the menſuration of angles. 2dly, Their complication and bulk render it difficult to apply them to a variety of teleſcopes, eſpecially to pocket ones. 3dly, They do not meaſure the angle without ſome loſs of time, which muſt be neceſſarily employed in turning the ſcrew, or in moving ſome other mechaniſm. 4thly, and laſtly, They are ſo expenſive, as for ſome of them to coſt much more than a tolerable good teleſcope.

The Mother-of-pearl MICROMETER is a very ſimple, and, at the ſame time, a very accurate inſtrument of the kind. It conſiſts of a ſmall ſemitranſparent ſcale or ſlip of Mother-of-pearl, about the 20th part of an inch broad, and of the thickneſs of common writing paper, divided into a num-

ber of equal parts by parallel lines, every fifth and tenth of which is a little longer than the rest.

The value of the divisions of the Micrometer must be ascertained in every telescope to which this instrument is adapted. This should be done by the opticians; and the ascertained value ought to be marked in the inside of the cap of the telescope, or in some other convenient part about it. When the value of the divisions has been once ascertained, the measurement of any required angle is not attended with any difficulty. Suppose, for example, that the divisions of a Micrometer in a telescope have been found to be each equal to an angle of 2 minutes and 3 seconds, and that you want to ascertain the angle subtended by the moon. Looking through the telescope, observe how many divisions of the Micrometer measure the disk of the moon exactly, multiply this number by the value of one division; *viz.* 2′. 3″, and the product is the angle required. Thus, if the moon

moon be meaſured by 15 diviſions, multiply $2'.3''$ by 15, and the product, $30'.45''$ is the angle ſubtended by the moon.

This Micrometer is ſituated in the focus of the eye-glaſs of the teleſcope, juſt where the image of the object is formed, and with its divided edge paſſing through the centre of the field of view; though this is not of abſolute neceſſity. It is immaterial whether the teleſcope be a refractor or a reflector, provided the eye-glaſs be a convex lens, and not a concave one, as in the Galilean conſtruction.

The ſimpleſt way of fixing it, is to ſtick it upon the diaphragm, which generally ſtands within the tube, and in the focus of the eye-glaſs. When thus fixed, if you look through the eye-glaſs, the diviſions of the Micrometrical Scale will appear very diſtinct, unleſs the diaphragm is not exactly in the focus of the eye-glaſs, in which caſe it muſt be moved to the proper place; or the Micrometer may be placed exactly in the focus of the eye-lens by the inter-

poſition of a circular piece of paper, card, or by means of bits of wax. This conſtruction is fully ſufficient when the teleſcope is always to be uſed by the ſame perſon; but when different perſons are to uſe it, then the diaphragm, which ſupports the Micrometer, muſt be conſtructed ſo as to be eaſily moved backwards or forwards, though that motion needs not be greater than about a tenth of an inch. This is neceſſary, becauſe the diſtance of the focus of the ſame lens appears different to the eyes of different perſons; and therefore, whoever is going to uſe the teleſcope for the menſuration of an angle, muſt firſt of all unſcrew the tube that contains the eye-glaſs and Micrometer, from the reſt of the teleſcope, and, looking through the eye-glaſs, muſt place the Micrometer where the diviſions of it may appear quite diſtinct to his view. In this ſhifting of the place, the value of the diviſions is ſo little altered as not to occaſion any ſenſible error.

If any perſon ſhould not like to ſee al-

ways

ways the Micrometer in the field of the telescope, then the Micrometrical scale, instead of being fixed to the diaphragm, may be fitted to a circular perforated plate of brass, of wood, or even of paper, which may be occasionally placed upon the said diaphragm.

When an object is in the field of the telescope just before the Micrometer, the semitransparency of the Mother-of-pearl renders the boundaries or edges of it very distinctly visible; yet the safest way of measuring the object, is by observing it just where it coincides with the divided edge of the Micrometer, in which place an accurate observer may measure the object with great accuracy, even to less than a quarter of a division; for the image of a luminous object seen through the semitransparent substance of the Micrometer is a little larger, and the image of a dark object is a little smaller, than the truth.

The use of this Micrometer is attended with a peculiar and considerable advan-

tage; namely, that with it the angle subtended by an object may be measured very exactly, even when the divisions of the Micrometer are by no means exact or equidistant; for if the same object be measured in different parts of the Micrometer, and a mean be taken of the different measurements, the result will be very exact, though the Micrometer itself be not accurately divided. Thus, suppose that the diameter of the moon measured on different parts of the Micrometer be found in one measurement to be 31′, in a second measurement to be 32′, and in a third to be 34′. Add these various observations together, divide the sum by the number of observations, and the quotient is the true angle subtended by the moon; *viz.*

$$\begin{array}{r} 31 \\ 32 \\ \underline{34} \end{array}$$

3 ) 97 ( $32'\frac{1}{3}$, or 32′. 20″. The true angle.

It

It is now necessary to shew the method of ascertaining the value of the divisions of the Micrometer, after which we shall consider its various uses.

### *Method of ascertaining the Value of the Divisions of the* MICROMETER.

Direct the telescope to the sun, and observe how many divisions of the Micrometer measure its diameter exactly. Then take out of the Nautical Almanack the diameter of the sun for the day in which the observation is made; divide it by the above-mentioned number of divisions, and the quotient is the value of one division of the Micrometer. Thus, suppose that 26½ divisions of the Micrometer measure the diameter of the sun, and that the Nautical Almanack gives for the measure of the same diameter 31′, 22″, or (by reducing it all into seconds) 1882″. Divide 1882″ by 26,5, and the quotient, neglecting a small remainder, is 71″, or 1′. 11″, which is the value

value of one division of the Micrometer. The double of which is the value of two divisions; the treble is the value of three divisions; and so on.

## *Another Method of ascertaining the Value of the* MICROMETER, *viz.*

### BY THE MOTION OF THE FIXED STARS.

Direct the telescope to a known fixed star, and so as to let the Micrometer be in the plane of the star's motion, which, by a few trials, is easily found out. Whilst the telescope remains fixed in that situation, observe (by means of a stop watch, or by the help of an assistant who counts the seconds upon a clock) the time employed by the star in passing along a certain number of the divisions of the Micrometer; for instance, 20 divisions *. Turn that time

* The light of the star alone, if it be of the first or second magnitude, is sufficient to enable the observer to count the divisions, when the Micrometer is placed just before the star.

into angular ſpace *. Divide this ſpace by the abovementioned number of diviſions of the Micrometer, and note the quotient. Take the natural coſine of the ſtar's declination by the help of tables VII. and XVII. of the tables requiſite for the Nautical Almanack; then ſay, as radius is to the coſine of the ſtar's declination, ſo is the above-mentioned quotient to a fourth proportional; which is the required value of one diviſion of the Micrometer.

When the ſtar is in the equator or very near it, then you need only convert the time of its paſſing along a certain number of diviſions into ſpace, and divide that ſpace by the number of diviſions, the quotient of which is the value required.

* This may be done by the table for reducing time into parts of the equator, and *vice verſa*, which table is inſerted in almoſt every aſtronomical book; or elſe by ſaying, as 60′ of time is to 15° of ſpace, ſo is the time of the paſſage of the ſtar to a fourth proportional, which is the ſpace required.

The

The following ſtars being very near the equator may be employed for this purpoſe; and the correction may be neglected, unleſs the teleſcope be a very powerful one, and great accuracy required.

| Names. | Magnitudes. | Right Aſcenſion. | Declination. |
|---|---|---|---|
| | | ° ′ ″ | ° ′ ″ |
| δ in the Whale | 3 | 37. 3. 20. | 0. 37. 50. S. |
| δ in Orion | 2 | 80.11. 42. | 0. 28. 40. S. |
| υ in the Lion | 4 | 171.25. 21. | 0. 23. 22. N. |
| η in Virgo | 3 | 182. 9. 57. | 0. 33. 27. N. |
| ζ in Virgo | 3 | 200.52. 36. | 0. 32. 13. N. |
| η in Antinous | 4 | 295.19. 1. | 0. 27. 22. N. |
| π le *Verſau* | 4 | 333.30. 39. | 0. 16. 3. N. |
| λ in Piſces | 5 | 352.42. 33. | 0. 34. 17. N. |
| γ in Virgo | 3 | 187.38. 11. | 0. 14. 22. S. |

*Example.*

*Example.* Suppofe that the ftar Aldebaran, in the conftellation called the Bull, be obferved to pafs through 30 divifions of the Micrometer in 44″ of time: It is required from thence to determine the value of the divifions of the Micrometer; the declination of Aldebaran being 16°. 3′.

The 44″ of time converted into fpace give 11′; and 11′, or (by converting them into feconds) 660″ divided by 30 (the number of divifions) give 15″ for the value of each divifion of the Micrometer. But as the ftar Aldebaran is not in the equator, this value muft be corrected by the following analogy; *viz.* as radius is to the natural cofine of 16°. 3′; fo is 15″, to a fourth proportional, *viz.* $100000 : 96102 :: 15'' : \frac{9610 \times 215}{100000}$ $= 14'', 4$; which is the correct value of each divifion of the Micrometer.

*Example* 2d. Suppofe that the ftar marked $\delta$ in Orion be obferved to pafs along 30 divifions of the Micrometer in 29″ of time, and

and that from this observation you wish to determine the value of the divisions of the Micrometer:

The 29″ of time are equal to the angular space of 7′. 15″.; or of 435″.; which number divided by 30 (the number of divisions) gives 14″,5 for the value of each division, which requires no correction, this star being very near the equator, as appears from the preceding table.

## *Another very easy Method of ascertaining the Value of the Divisions*, &c.

THERE is also a very easy method of ascertaining the value of a Micrometer, by the help of another telescope furnished with a Micrometer of known value. The practical operation is as follows. Observe through the standard telescope a celestial object, or a very distant land object, as the distance between any two fixed stars, the diameter of the sun, the diameter of a tree, the top of a chimney, &c. and set down the

the angle ſubtended by that object as given by its Micrometer; then obſerve the ſame object through the teleſcope with the Micrometer, whoſe value you want to aſcertain, and ſet down the number of diviſions which appear to meaſure that object. Laſtly, divide the above-mentioned angle by the ſaid number of diviſions, and the quotient is the required value of each diviſion. Thus, if the diameter of the ſun be found to ſubtend an angle of 32 minutes by the Micrometer of the ſtandard teleſcope, and to be meaſured by 48 diviſions of the Micrometer in queſtion; divide 32′, or 1920″ by 48, and the quotient 40″. is the required value of each diviſion.

This method is perhaps the moſt eligible for the Opticians, on account of its expedition, and becauſe they may always keep a teleſcope by way of ſtandard expreſsly for this purpoſe. It is almoſt needleſs to obſerve, that the ſtandard teleſcope ought to be a pretty good one, and the value of its Micrometer well aſcertained.

Whichever

Whichever of the above-mentioned methods be used, it is always improper to rely on a single observation; for the value of the Micromoter ought to be ascertained by two or more repetitions of one, or of different methods; and from thence a mean taken of the different results.

The value of the Micrometer once ascertained, remains unaltered as long as the telescope continues the same, *viz.* as long as the distance between its lenses is not altered. But in viewing objects at different distances, the eye tube of the telescope must be drawn farther out, or pushed farther in, so as to adjust the focus for distinct vision, and then the value of the Micrometer is subject to some alteration, which, however, is very trifling, and may be safely neglected in all the purposes for which the Micrometer is employed; except in measuring objects which are nearer than about 200 times the length of the telescope; in which case the error becomes too sensible. However, even in this case, the error may be

be corrected; but I shall embrace some other opportunity of describing the accurate method, it being rather too intricate for the generality of readers.

*Of the various Uses to which a Telescope furnished with a* MICROMETER *may be applied.*

All the following purposes, if properly considered, will be found to depend upon the same property; for, in fact, a Telescopical Micrometer can only shew the angle subtended by an extension of any sort, as the diameter of the sun, the distance between two stars, &c.; they are, however, here enumerated, for the sake of shewing the reader that so simple an instrument can be applied more frequently, and to a greater variety of purposes, than he may perhaps at first imagine.—It may be used

1. For meaſuring the apparent diameter of the ſun, moon, and planets.

2. For meaſuring the apparent diſtances of the ſatellites from their planets.

3. For meaſuring the cuſps of the moon in eclipſes.

4. For meaſuring the apparent diſtances between two contiguous ſtars, between a ſtar and a planet, between a ſtar and the moon, or, laſtly, between a comet and the contiguous ſtars, and hence the ſituation or path of the comet may be aſcertained.

5. For finding the difference of declination of contiguous ſtars when they have nearly the ſame right aſcenſion.

6. For meaſuring the ſmall elevations or depreſſions of objects above and below the horizon.

7. For meaſuring the proportional parts of buildings, and other objects in perſpective drawing.

8. For aſcertaining whether a ſhip at ſea, or any moving object, is coming nearer, or going farther off.

9. For aſcertaining the real diſtances of objects of known extenſion, and hence to meaſure heights, depths, and horizontal diſtances, as roads, rivers, heights of houſes, &c.

10. For meaſuring the real extenſions of objects, when their diſtances are known.

11. For meaſuring the diſtance and ſize of an object when neither of them is known.

To thoſe purpoſes we may add two more, in which the eye tube only of the teleſcope is uſed when the Micrometer is adapted to thoſe teleſcopes which contain four glaſſes in the eye tube; in ſuch caſe the ſaid eye tube being unſcrewed from the teleſcope, ſerves as a microſcope, and then the Micrometer may be uſed.

12. For meaſuring the real or lineal dimenſions of ſmall objects, inſtead of the angles.

13. For meaſuring the magnifying powers of other teleſcopes.

With reſpect to the firſt ſeven uſes, nothing more needs be ſaid in order to explain them; for when the value of the diviſions of the Micrometer is known, mere inſpection will anſwer; remembering only what has been already obſerved in the preceding pages, namely, that it is better to take the meaſurement when the object, or

that

that part of the object which is intended to be meaſured, is contiguous to the divided edge of the Micrometer, than when it ſtands before the Micrometer, and is ſeen through it.

The method of aſcertaining whether a ſhip, or other moving object, is approaching or receding, is likewiſe very ſimple and evident; for if the angle ſubtended by the moving object appears to increaſe, it ſhews that the object is coming nearer, and on the contrary, if the angle appears to decreaſe, it ſhews that the object is going farther off.

The diſtances of objects of known extenſion, or their real extenſions when the diſtances are known, muſt be aſcertained by means of trigonometrical calculations from the angle after having been meaſured with the Micrometer; but for the ſake of expedition, or for thoſe perſons who are not acquainted with trigonometry, thoſe calculations will be found made out in the following Table, the uſe of which is very

ſhort and eaſy. This, however, is only meant for common purpoſes; for when the obſervations are required to be very accurate, and ſingle ſeconds or parts of a ſecond are to be included, as frequently happens in aſtronomy, in that caſe the calculations muſt be made according to the uſual rules of trigonometry, with the help of logarithmical tables.

TABLE

# TABLE

## FOR

Computing the DISTANCE of an Object from the Place of Obſervation, when its Extenſion, and the Angle ſubtended by it, are known;

## OR,

For finding the EXTENSION of the Object when the Diſtance and ſubtended Angle are known.

| | 0." | 10." | 20." | 30." | 40." | 50." |
|---|---|---|---|---|---|---|
| 0' | 0 | 20625 | 10312 | 6876 | 5156 | 4126 |
| 1 | 3438 | 2946 | 2579 | 2292 | 2063 | 1875 |
| 2 | 1719 | 1586 | 1473 | 1379 | 1298 | 1213 |
| 3 | 1146 | 1085 | 1031 | 982 | 938 | 897 |
| 4 | 859,4 | 825 | 793 | 764 | 737 | 711 |
| 5 | 687,5 | 665 | 645 | 626 | 607 | 589 |
| 6 | 573 | 559 | 543 | 529 | 516 | 503 |
| 7 | 491 | 479 | 469 | 458 | 448 | 439 |
| 8 | 430 | 421 | 412 | 404 | 397 | 389 |
| 9 | 382 | 375 | 368 | 362 | 355 | 349 |
| 10 | 344 | 338 | 333 | 328 | 322 | 317 |
| 11 | 312,5 | 308 | 303 | 299 | 295 | 291 |
| 12 | 286,5 | 283 | 279 | 275 | 271 | 268 |
| 13 | 264,4 | 261 | 258 | 255 | 252 | 248 |
| 14 | 245,6 | 243 | 240 | 237 | 235 | 232 |
| 15 | 229 | 227 | 224 | 222 | 220 | 217 |
| 16 | 215 | 213 | 210 | 208 | 206 | 204 |
| 17 | 202 | 200 | 198 | 296 | 195 | 193 |
| 18 | 191 | 189 | 188 | 186 | 184 | 183 |
| 19 | 181 | 179 | 178 | 176 | 175 | 173 |
| 20 | 172 | 170 | 169 | 167 | 166 | 165 |
| 21 | 164 | 162 | 160,6 | 159,5 | 158,4 | 157 |
| 22 | 156 | 155 | 154 | 153 | 152 | 150,6 |
| 23 | 149,5 | 148,4 | 147,4 | 146 | 145 | 144 |
| 24 | 143 | 142 | 141 | 140,4 | 139,4 | 138,5 |
| 25 | 137,5 | 137 | 136 | 135 | 134 | 133 |
| 26 | 132 | 131,4 | 130,6 | 130 | 129 | 128 |
| 27 | 127 | 126 | 125,6 | 125 | 124 | 123,5 |
| 28 | 123 | 122 | 121 | 120,6 | 120 | 119 |
| 29 | 118,5 | 118 | 117,4 | 117 | 116 | 115 |
| 30 | 114,6 | 114 | 113 | 113 | 112 | 111,5 |

| | 0.″ | 10.″ | 20.″ | 30.″ | 40.″ | 50.″ |
|---|---|---|---|---|---|---|
| 31′ | 111 | 110,4 | 110 | 109 | 108,6 | 108 |
| 32 | 107,4 | 106,7 | 106 | 106 | 105 | 105 |
| 33 | 104 | 113,6 | 113 | 102,6 | 102 | 101,6 |
| 34 | 101 | 100,6 | 100 | 100 | 99 | 99 |
| 35 | 98 | 97,5 | 97 | 97 | 96 | 96 |
| 36 | 95,5 | 95 | 94,5 | 94 | 94 | 93,3 |
| 37 | 93 | 92,5 | 92 | 92 | 91,3 | 91 |
| 38 | 90,5 | 90 | 90 | 89 | 89 | 88,5 |
| 39 | 88 | 87,6 | 87 | 87 | 86,5 | 86 |
| 40 | 86 | 85,6 | 85 | 85 | 84,4 | 84 |
| 41 | 84 | 83,4 | 83 | 83 | 82,4 | 82 |
| 42 | 82 | 81,4 | 81 | 81 | 80,5 | 80 |
| 43 | 80 | 79,6 | 79,3 | 79 | 78,7 | 78,4 |
| 44 | 78 | 78 | 77,6 | 77,3 | 77 | 76,7 |
| 45 | 76,4 | 76 | 75,7 | 75,5 | 75 | 75 |
| 46 | 75 | | | 73,6 | | |
| 47 | 73 | | | 72,3 | | |
| 48 | 71,6 | | | 71 | | |
| 49 | 70 | | | 69,4 | | |
| 50 | 69 | | | 68 | | |
| 51 | 67,4 | | | 66,7 | | |
| 52 | 66 | | | 65,5 | | |
| 53 | 65 | | | 64 | | |
| 54 | 64 | | | 63 | | |
| 55 | 62,5 | | | 62 | | |
| 56 | 61,4 | | | 61 | | |
| 57 | 60,3 | | | 59,7 | | |
| 58 | 59,3 | | | 58,7 | | |
| 59 | 58,3 | | | 57,8 | | |
| 60 | 57,3 | | | 56,8 | | |

PROBLEM

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PROBLEM Ist. To determine the diſtance of an object, when its ſize and the angle ſubtended by it, are known.

The numbers in the preceding table, which correſpond to the angles marked in the left-hand column and upper horizontal column, ſhew how many times the diſtance of the object is greater than its ſize; and therefore if they are multiplied by the ſize or extenſion of the object, the products are the required diſtances, which are of courſe expreſſed by inches or feet, or any other meaſures, according as the extenſions of the objects are expreſſed by inches, or feet, or any other like meaſure.

*Example* 1ſt. Suppoſe that the trunk of a tree, which is known to be three feet in diameter, be obſerved, by means of the Teleſcopical

Telescopical Micrometer, to subtend an angle of 9.′ 30.″, from which data its distance from the place of observation is to be determined. Take the number answering to the angle of 9.′ 30.″ out of the table, which is 362, multiply it by the diameter of the tree, *viz.* three feet; and the product 1086, shews that the said tree is 1086 feet distant from the place of observation, or, more precisely, from the object end of the telescope.

*Example* 2d. Suppose that a pane of glass in the window of a house be found to measure 9 inches in breadth, and that the said pane viewed through the telescope from another house, be found to subtend an angle of one minute and a half. Take the number answering to 1.′ 30″, out of the table; multiply it by 9 inches (*viz.* 2292 × 9) and the product shews that the distance between the two houses is 20628 inches, or 1719 feet.

PROBLEM II. To determine the extension of an object, when its distance, and the angle subtended by it, are known.

This problem is the converse of the first; therefore divide the distance by the tabular number answering to the subtended angle, and the quotient is the extension of the object.

*Example*. Let it be required to ascertain the height of a man who stands at the distance of one mile, or of 5280 feet; having observed by means of the Telescopical Micrometer, that he subtends an angle of 3.′ 50.″ Divide 5280 feet by 897, which is the tabular number answering to 3.′50.″, and the quotient is the required height of the man; *viz*. 5 feet and 10¾ inches.

PROBLEM III. To aſcertain the diſtance and ſize of an object, when neither of them is known.

In order to reſolve this problem, the angle ſubtended by the object muſt be obſerved from two ſtations, both in the ſame ſtraight line with it; one ſtation being nearer than the other. The diſtance between the two ſtations muſt be meaſured likewiſe. Then the diſtance of the object from the fartheſt ſtation is determined by the following rule: Multiply the larger angle by the diſtance between the two ſtations; divide the product by the difference between the two angles, and the quotient is the diſtance required *.

Having

* Let $T$, $t$ denote the tangents of the two obſerved angles, d the meaſured diſtance between the two ſtations, y the unknown diſtance of the object from the fartheſt ſtation, y—d the diſtance of the object from the neareſt ſtation, r the radius, and x the unknown ſize of the object.

Then

Having ascertained the distance, the size of the object is found by means of Problem 2d.

*Example.* Let the two observed angles be 14.′ and 16.′; and the distance measured between the two stations be 30 feet. Then the product of 16 multiplied by 30 is 480; and this number divided by two, (which is the difference between the two angles) gives 240 for the distance of the object from the farthest station.

Then the object, being perpendicular to the axis of the telescope, is, (in small angles, such as are measured with a Micrometer) as the tangent of the subtended angle; therefore by the rules of trigonometry we have $r : t :: y : x$ and $r : T :: y—d : x$; hence $rx = ty$, and $rx = Ty—Td$; therefore $ty = Ty—Td$, and $Ty—ty = Td$, which divided by $T—t$ gives $y = \frac{Td}{T—t}$: But in small angles the tangents are as the angles; therefore the distance y is equal to the product of the larger angle multiplied by the distance between the two stations, and then divided by the difference between the two angles.

It

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It is necessary to observe, that in the practical solutions of the preceding problems, there are several particulars which must be carefully attended to; otherwise the results will not be attended with the accuracy required.

First of all it must be observed, that in order to measure an angle with accuracy, the telescope ought to have a stand, or be otherwise rendered steady; but yet without such precaution, one may easily acquire the practice of measuring an angle with accuracy sufficient for many purposes, by holding a telescope in the hands, especially when one end of it rests against a tree, a door, the side of a window, &c.

With respect to the preceding table of numbers and angles, the reader will perceive that it contains only the numbers of the angles for every 10.″ up to 45.′, and for every half minute from thence to a whole degree: yet the numbers for the intermediate angles may be obtained

tained very easily; *viz.* by taking a proportional part of the difference between the numbers of the preceding and succeeding angles, and adding it to the least number. Thus, to find the numbers answering to 4.′ 15.″ subtract 793 from 825; add half the remainder, *viz.* 16 to 793; and the sum 809 is the number answering to 3.′ 15.″. Thus also we find that the number for the angle of 42″, is 4332; and for the angle 5.′ 16.″ is 657. As the differences between those numbers decrease very fast when the angle is greater than 20 or 25 minutes, there is no occasion to add any proportional part for the odd seconds; thus, for the angle of 28.′ 44.″ you take the number answering to 28.′ 40.″ Thus, also, 64 serves with equal propriety for the angle of 53.′ 45.″, or for 53.′ 20.″, as for 53.′ 30.″ and so of the rest.

In measuring an object with the Micrometer, it is requisite for the object to be as nearly as possible perpendicular to the axis of the telescope, or to the visual line. If a man,

man, for inſtance, ſtands on the top of a hill, and the obſerver is ſituated below the hill, the angle ſubtended by the height of the man is ſmaller than it ought to be, or than if he ſtood on the ſame level with the obſerver; becauſe, in the former caſe, he is not perpendicular, but inclined, to the viſual line. In order to ſubtend a proper angle, the man on the top of the hill ought to lay himſelf down acroſs the viſual line or axis of the teleſcope. For the ſame reaſon, when a diſtance is to be aſcertained from the meaſurement of the window of a houſe, if the obſerver ſtands above or below the level of the window, he muſt meaſure the breadth of the window; but if his ſituation, though on the ſame level, be oblique and not ſtraight before the front of the houſe, he muſt in that caſe meaſure the height of the window, that extenſion being now perpendicular to the axis of the teleſcope.

When an inacceſſible diſtance is to be meaſured from a fixed place; as for ex-

ample, the distance of a town, when a river or marshy ground is interposed, or the distance between the land and a ship at sea, the best way is to take the angle subtended by a man, and to estimate the distance from it, reckoning the man to be at a mean six feet high when dressed in the usual manner with shoes and hat. But as this height is subject to considerable variation, it is therefore not only proper, but necessary to take the angles subtended by several men, and to calculate the distance in question from each of them separately; for if then you take a mean of all those results, you will attain a greater degree of accuracy, than by any single observation whatever.

*Example.* Suppose it be required to ascertain the distance of an island from a ship at sea: Take the angles subtended by four men, and suppose those angles to be 3.′ 20.″; 3.′ 30.″; 3.′ 30.″; and 3.′ 40.″ Multiply each of the tabular numbers answering

ſwering to thoſe angles, by ſix feet, the mean height of a man, and you will have the following diſtances; *viz.* 6168; 5892; 5892; 5628. Add them all together, and divide the ſum by the number of obſervations, *viz.* 4. The quotient gives 5899½ feet for the required diſtance.

The laſt precaution I ſhall take notice of, is relative to the different magnifying powers, and the conſequent different values of the Micrometer, in proportion to the various diſtances of the objects. The error reſulting therefrom may be corrected to a great degree of accuracy, by a method which will be publiſhed at ſome other opportunity: but it will, however, be neceſſary to mention, that in meaſuring diſtances, when the object is nearer to the place of obſervation than 200 times the length of the teleſcope, the calculated diſtance is ſenſibly *ſhorter* than the real one, and therefore ſomething muſt be added to it. In order to avoid minuteneſs and com-

plex calculation, the following rule will answer with tolerable accuracy: When the distance of the object is less than 200 times, and more than 150 times the length of the telescope, you may increase the calculated distance by the 300dth part of itself: when the distance of the object is between 150 and 100 times the length of the telescope, you may increase the calculated distance by the 200dth part of itself; and when the object is between 50 and 100 times the length of the telescope, you may increase it by the 100dth part of itself. The following *Example* will sufficiently illustrate the operation.

Suppose that with a telescope of 2 feet, furnished with a Micrometer, you find that a foot ruler placed at a certain distance, subtends an angle of 27.'; then, according to Problem 1st, its distance from the object end of the telescope is 127 feet. But as 127 feet is between 50 and 100 times the length of the telescope, take the

100dth

100dth part of 127, which is 1,27; add it to 127, and their sum, 128,27 feet, is the corrected distance.

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In the enumeration of the various uses of the Micrometer, we mentioned two, in which only the eye tube of the telescope must be employed. This is particularly applicable to the pocket acromatic Telescopes of 14 and 20 inches, consisting of four tubes, the smallest of which contains four lenses, with the Micrometer situated between the two lenses that are nearest to the eye. If this tube be unscrewed from the rest of the telescope, and be applied to small objects, it will serve for a microscope, having a considerable magnifying power; and the Micrometer will in that case measure the lineal dimensions of the object, as, the diameter of a hair, the limbs of an insect, &c.

In order to find the value of the divisions of the Micrometer for this purpose, you need only apply a ruler divided with

tenths of an inch, to the end of the tube, and looking through the tube, obſerve how many diviſions of the Micrometer meaſure one tenth of an inch on the ruler, which will give the required value. Thus, for inſtance, if 30 diviſions are equal to one tenth of an inch, 300 of them muſt be equal to one inch, and one diviſion is equal to the 300dth part of an inch; which being once aſcertained, may be ſet down ſomewhere on the teleſcope, ſo as to be always at hand to be referred to if forgotten. The beſt way is, to ſtick, by means of wax, a circle of paper in the inſide of the cap of the teleſcope, with both the values of the Micromoter marked upon it; *viz.* when the inſtrument is uſed as a teleſcope to meaſure angles, and when it is uſed as a microſcope to meaſure the lineal dimenſions of ſmall objects.

It is in the ſtate of a microſcope that the eye tube of a teleſcope with a micrometer may be employed for meaſuring the magnifying powers of other teleſcopes with great

great accuracy, by meaſuring the diameter of the pencil of light at the eye end of the teleſcope in queſtion; for if you divide the diameter of the object lens, or of the aperture of the teleſcope, by the diameter of the ſaid pencil of light, the quotient will expreſs how many times that teleſcope magnifies in diameter. The practical operation is as follows:

Take the eye tube, together with the tube next to it, and apply the aperture of the latter to the eye-end of the teleſcope whoſe magnifying power you wiſh to aſcertain, and hold it ſteady againſt that end; then looking through the firſt tube, move it backward and forward in the other, until the pencil of light of the teleſcope in queſtion appears quite round and well defined, in which ſituation obſerve how many diviſions of the Micrometer meaſure the diameter of it. You muſt alſo meaſure the diameter of the object lens in inches and tenths, by applying a divided ruler to it. This done, multiply the dia-

meter of the object lens by the number of divisions of the Micrometer, which is equal to one inch; divide the product by the number of divisions which measure the pencil of light, and the quotient is the magnifying power of the telescope. Thus, suppose that 300 divisions of the Micrometer are equal to the apparent extension of one inch, that the pencil of light is measured by 4 of those divisions, and that the diameter of the object lens measures one inch and two tenths. Multiply 1,2 by 300, and the product 360 divided by 4, gives 90 for the magnifying power of the telescope.

I have applied such a tube as the one just described, to another very important use; namely, instead of a nonius, to the subdivision of the parts of a circle; for which purpose it answers incomparably better than any other contrivance, and nothing can be more simple. In this case, the tube must be constructed so as to admit of a little motion between the last lens

and the one next to it, for by that means the value of the Micrometer may be increaſed or diminiſhed at pleaſure, ſo as to let a proper number of its diviſions become equal to a given extenſion; otherwiſe it would be very difficult, and next to impoſſible, to cut the Micrometer ſo as to make any number of its diviſions equal to a certain part of the arch of a circle; as for inſtance, 30 diviſions equal to half a degree, and of courſe each diviſion equal to one minute.

8.7.07.

FINIS.

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